

WATER QUALITY ASSESSMENT OF ROCKY LAKE, MANITOBA, CANADA

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Water Quality Assessment of Rocky Lake, Manitoba, Canada Manitoba Conservation, March 2000

BACKGROUND

Rocky Lake (54° 09' N, 101° 30' W) lake is situated approximately 40 km north of The Pas. It is a large irregularly shaped lake, separated into a large main basin to the northeast and a smaller secondary basin to the southwest. Most of the inlet streams enter the southwest basin and it is from this basin that the lake drains through a series of small lakes into the Saskatchewan River. The lake has a surface area of 11,687 hectares and a mean depth of 4.8 m (Leroux 1984). The northeast basin of the lake is relatively large with a maximum depth of just over 10 m while the southwest basin is smaller and is under 4 m in depth (Figure 1). The northwest basin has surficial glaciolacustrine deposits overlying limestone bedrock, with exposed bedrock along a considerable portion of the shoreline (Weir 1983). The southwest basin surficial deposits are mainly fen, marsh, and swamp, with some exposed limestone rock. Soils appear to be mixed with Humic Gleysol, gray Luvisol, and Eutic Brunisol. The surrounding vegetation is mainly northern coniferous forest with some mixed woods.

There are two lodges that provide light housekeeping cabins and a private campground. There are also 121 lots with over 100 cottages and permanent homes located on the east and north shores of the northeastern Basin of Rocky Lake. The lake is mainly utilized for recreational activities including swimming, boating, and angling.

METHODS

Four water quality sampling sites were located on Rocky Lake. Rocky Lake sites WQ1981 and WQ1982 were located in the northeast basin near the areas where development has taken place. Sites WQ1983 was located at the entrance to the channel to the southwest basin and WQ1984 was located in the central area of the undeveloped southwest basin (Figure 1). On June 16, 1999 samples were collected at approximately 10 cm below the surface and 1 m off the bottom at each site. Water from these samples was analyzed for 83 variables including general chemistry, nutrients, fecal coliform bacteria, dissolved oxygen, major ions, heavy metals, pesticides and others. These analyses also included analysis for Mimic (Tebufenozide) a pesticide that had recently been sprayed in the area for the control of spruce budworm.

Subsequently, volunteers collected six more sets of water samples between the beginning of July and the mid September 1999. Water from the volunteer sampling was analyzed for phosphorus, various nitrogen compounds, fecal coliform bacteria, chlorophyll *a*, as well as pH, conductivity, and turbidity. Volunteer sampling procedure during the summer included measuring the Secchi disk depth. The Secchi disk is a 20 centimetre diameter black and white disk that is lowered into the water to a point where it disappears from sight and the depth that this occurs at is recorded. Samples were collected where possible throughout the water column to a depth of twice the Secchi disk depth. A depth of twice the Secchi disk depth is the approximate depth of the euphotic zone, or zone of light penetration where algal photosynthesis can occur. Volunteers also recorded water temperatures.

Data collected over the summer of 1999 were compared using Student's "t" tests. A Student's "t" test ($\alpha = 0.05$) was used to test for differences in concentrations between each water sampling site on



Figure 1. Water quality sampling sites on Rocky Lake (Surveys and Mapping Branch 1977).

Rocky Lake. With the exception of pH, all data was transformed to a log base prior to the statistical analysis in order to stabilize variances.

Water Quality Index

Water quality is typically assessed by measuring a large number of variables, including bacteria, plant nutrients, major ions, trace metals, industrial organics, agricultural pesticides and many others. The Canada Water Quality Index (CWQI) was used to describe the overall quality of water in Rocky Lake. Some 25 variables were compared with both national water quality guidelines (CCME 1988 and subsequent updates) and Manitoba-specific water quality objectives (Williamson 1988) to calculate the CWQI.

The CWQI mathematically incorporates information on water quality from three factors. The basic premise of the index is that water quality is excellent when all water quality guidelines or objectives set to protect water uses are met virtually all the time. When guidelines or objectives are not met, water quality becomes progressively poorer. This depends upon the number of water quality variables for the objectives or guidelines that are not met (Factor 1), the percentage of time they are not met (Factor 2), and an asymptotic equation using the normalized sum of departures from objectives, and a constant factor β (Factor 3).

For example, progressively smaller index values result when guidelines or objectives are exceeded for more water quality variables (*i.e.*, exceedences for one variable will have less impact on water uses than simultaneous exceedences for many water quality variables), when exceedences occur during longer periods of time (*i.e.*, an exceedence for a brief period will have less impact on a water use than an exceedence for an extended period), and when the overall magnitude of exceedences increase (*i.e.*, an exceedence slightly above a water quality guideline or objective will have less impact on a water use than an exceedence that is several times higher). Thus, the index logically incorporates information on water quality based on comparisons to guidelines or objectives to protect important water uses. The CWQI ranges from 0 to 100 and was used to rank water quality in categories ranging from poor to excellent. An excellent CWQI rating (85-100) indicates that all water uses are protected, with a virtual absence of impairment or only a minimal degree of impairment. A good water CWQI rating (70-84) indicates that all water quality uses are protected with only a minor degree of impairment. A fair CWQI rating (55-69) indicates that most water uses are protected but a few may be impaired. A marginal CWQI rating (40-54) indicates that several water uses may be impaired while a poor CWQI rating (0-39) indicates that most water uses are impaired.

RESULTS AND DISCUSSION

The emphasis in the Rocky Lake study was on changes in phosphorus, nitrate-nitrite nitrogen, ammonia, total Kjeldahl nitrogen, chlorophyll *a*, turbidity, and bacteria over the summer of 1999. Temperature, pH, and conductivity were also measured in water samples from Rocky Lake over the summer of 1999. Average values for these variables are shown for each sampling date and at each of four sites for Rocky from June 16 to September 15. Appendix 1 includes all the results of analyses for each sample for the variables noted in Table 1. Analytical results for all 83 variables measured in water samples collected on June 16, 1999 are shown in Table 2 for Rocky Lake, respectively.

Table 1. Average nutrients, chlorophyll *a*, bacteria, temperature, pH, conductivity, and turbidity for each sampling date and at each of four sites, Rocky Lake, June 16 to September 15, 1999

Variable	Units	Date										Site			
		1999-06-16	1999-07-05	1999-07-18	1999-07-28	1999-08-10	1999-08-29	1999-09-15	WQ1981	WQ1982	WQ1983	WQ1984	AB		
Temperature	(°C)	17.4	16.3	20.0	—	19.5	18.0	14.3	18.1	17.8	18.3	17.5	17.9		
Fecal Coliform Bacteria	(Number/100 mL)	< 10	< 10	< 10	< 10	< 10	< 10	< 13	< 11	< 10	< 10	< 10	< 11		
pH	(pH units)	8.67	8.73	8.69	8.70	8.72	8.67	8.71	8.66	8.66	8.71	8.77	8.70		
Specific Conductivity	(mS/cm)	411	408	412	408	413	414	417	426	425	420	376	412		
Turbidity	(NTU)	2.2	1.8	2.7	5.5	3.2	7.1	9.0	2.8	3.1	2.9	9.3	4.5		
Secchi Disc	(m)	2.65	1.59	2.25	—	1.73	1.38	0.88	2.00	1.98	1.88	1.13	1.74		
Total Phosphorus	(mg/L)	0.0195	0.0170	0.0205	0.0285	0.0283	0.0306	0.0346	0.0232	0.0246	0.0229	0.0305	0.0253		
Particulate Phosphorus	(mg/L)	0.0118	0.0095	0.0133	0.0180	0.0203	0.0200	0.0220	0.0142	0.0157	0.0146	0.0211	0.0164		
Dissolved Phosphorus	(mg/L)	0.0078	0.0060	0.0073	0.0085	0.0080	0.0108	0.0128	0.0080	0.0080	0.0086	0.0084	0.0090		
Total Ammonia	(mg/L)	< 0.0041	0.0065	0.0043	0.0050	0.0100	0.0175	< 0.002	< 0.0073	< 0.0077	< 0.0066	< 0.0066	< 0.0071		
Un-ionized Ammonia	(mg/L)	< 0.00064	0.00122	0.00082	—	0.00205	0.00288	< 0.00029	< 0.00140	< 0.00133	< 0.00114	< 0.00140	< 0.00132		
Nitrate-Nitrite Nitrogen	(mg/L)	< 0.010	< 0.010	< 0.010	< 0.010	< 0.010	< 0.013	< 0.010	< 0.011	< 0.010	< 0.010	< 0.010	< 0.011		
Total Kjeldahl Nitrogen	(mg/L)	0.49	0.73	0.86	0.85	0.80	0.88	1.10	0.70	0.74	0.81	1.01	0.82		
Chlorophyll <i>a</i>	(µg/L)	< 1.0	1.8	2.0	5.3	—	4.8	< 1.3	< 2.0	< 2.7	< 2.0	< 4.0	< 2.7		

Table 2. All physical, chemical and biological variables, Rocky Lake, June 16, 1999.

[illegible]

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[illegible]

Nutrients

Nutrients required for the growth of algae and other plants include phosphorus and nitrogen compounds. Analyses were conducted for phosphorus, ammonia-ammonium nitrogen (also known as total ammonia), nitrate-nitrite nitrogen, and total Kjeldahl nitrogen. Also, un-ionized ammonia was calculated from the ammonia-ammonium nitrogen where pH and temperature at time of sampling were known. Average phosphorus and nitrogen are shown over time and per site in Figures 2 and 3.

Phosphorus often limits algae growth since it is likely to be the least abundant nutrient. During 1999, the average total phosphorus in Rocky Lake was 0.0253 mg/L (Table 1). Total phosphorus concentrations that exceed the water quality objective of 0.025 mg/L have the potential to cause algae blooms in Lake (Williamson 1988). Total phosphorus concentrations exceeded the water quality objective of 0.025 mg/L in 11 out of 32 occasions in water samples from Rocky Lake (Appendix 1). Although dissolved phosphorus remained relatively stable throughout the summer, total phosphorus concentrations tended to increase in the middle of the summer with the highest overall average phosphorus at site WQ1984 in the southwest basin (Figure 2). On July 28, 1999 the total phosphorus at site WQ1984 in the southwest basin was 0.36 mg/L while at the three locations in the main northeast basin were near but below the objective of 0.025 mg/L (Appendix 1). During August and September the average total phosphorus in each basin exceeded the objective.

Increases in total phosphorus appeared to be due mainly to increases in total particulate phosphorus increasing with turbidity. The highest overall average total phosphorus and the highest overall average turbidity occurred at site WQ1984 in the shallow southwest basin (Table 1 and Figures 2 and 4). Wind and wave action and possibly boating activity in this basin would have been particularly effective in re-suspending particulate phosphorus from the sediments. Some additional particulate phosphorus may have come from point source (e.g. sewage effluent) and non-point sources (e.g. fertilizers and soils washed in to the lake from lakeshore properties) in the developed areas in the northwest basin. However, considering the undeveloped nature of the southwest basin, where the highest average total phosphorus occurred, it is likely that most of the particulate phosphorus would have been re-suspended by wind and wave action in both basins. Also, total dissolved phosphorus was relatively low at all sites and remained relatively stable throughout the summer, increasing only slightly in September (Figure 2). There were no significant differences ($\alpha = 0.05$) in total phosphorus, total or total particulate phosphorus between any of the three sites in the northeast basin of Rocky Lake. However, total particulate phosphorus was significantly higher ($\alpha = 0.05$) at site WQ1984 in the southwest basin relative to each site in the northwest basin of the lake. Total phosphorus was significantly higher ($\alpha = 0.05$) at site WQ1984 in the southwest basin relative to sites WQ1981 and WQ1983 in the northwest basin of the lake. There were no significant differences in total dissolved phosphorus between any of the sites in either basin of Rocky Lake.

Nitrogen compounds were present at low concentrations for ammonia, and nitrate-nitrite, but moderately high concentrations of total Kjeldahl nitrogen in Rocky Lake (Table 1, Figure 3, and Appendix 1). Total Kjeldahl nitrogen increased considerably over the summer (Figure 2). Average total Kjeldahl nitrogen concentrations were 0.82 mg/L for Rocky ranging from and average concentration of 0.70 mg/L at site WQ1981 in the northeast basin to 1.01 mg/L at site WQ1984 in the southwest basin (Table 1 and Figure 2). Total Kjeldahl nitrogen concentrations were significantly higher ($\alpha = 0.05$) at site WQ1984 in the southwest basin relative to any of the three sites in the northeast basin. Also, in the northeast basin total Kjeldahl nitrogen concentrations were also significantly higher ($\alpha = 0.05$) at site WQ1983 relative to site WQ1981. Since sites WQ1983 and WQ1984 are located furthest from developed areas, on the east and north shores, of the northeast basin the increase in total nitrogen is unlikely to have been due to anthropogenic activities (Figure 1). Nitrate and nitrite nitrogen concentrations were at or near detection limits of 0.01 mg/L and were well below the water quality

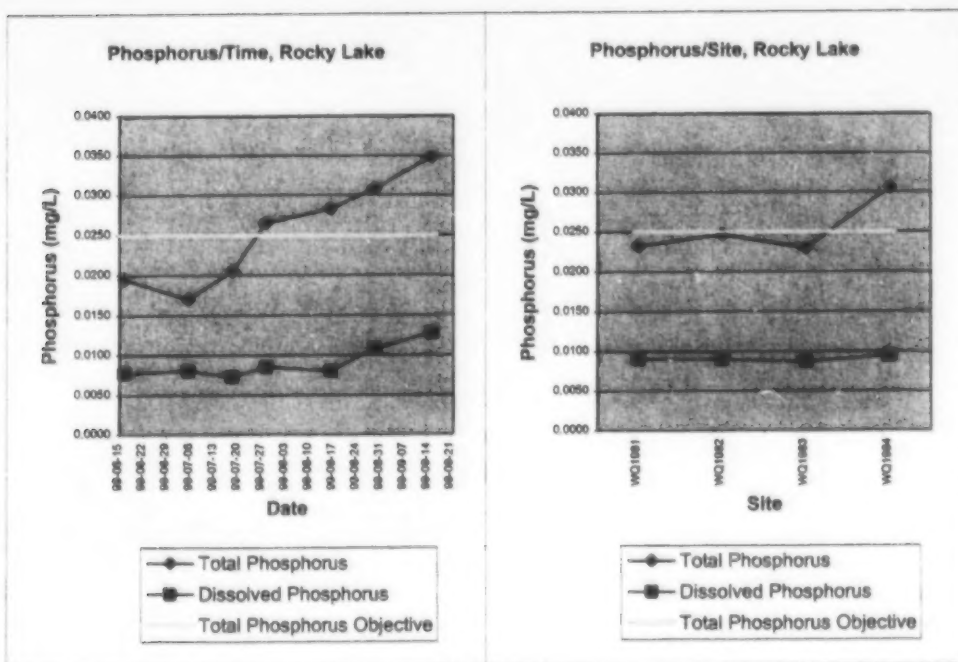


Figure 2. Average phosphorus over time and at each site, Rocky Lake 1999.

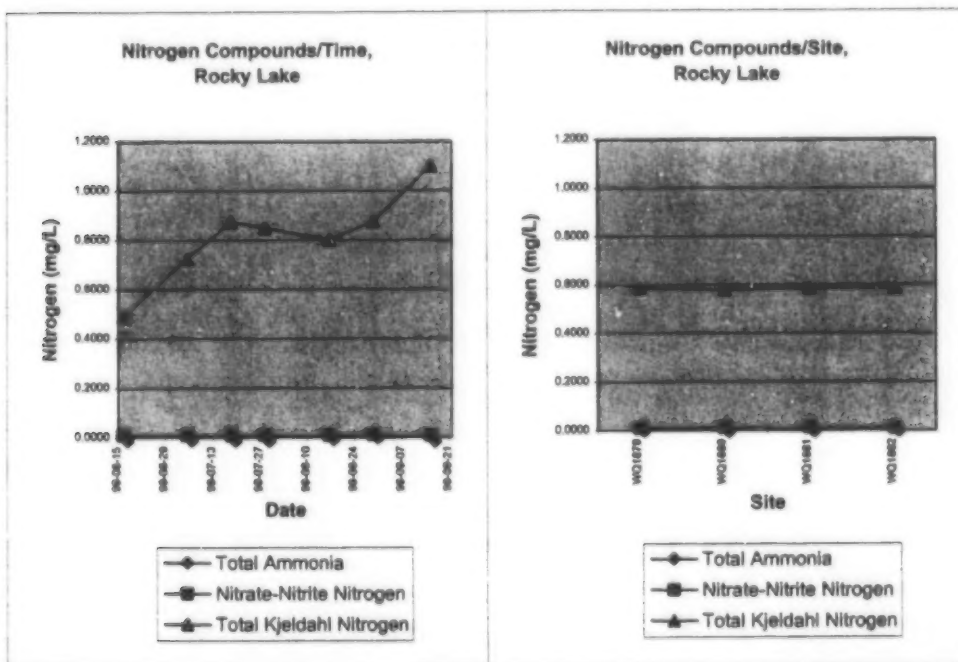


Figure 3. Average nitrogen compounds over time and at each site, Rocky Lake 1999.

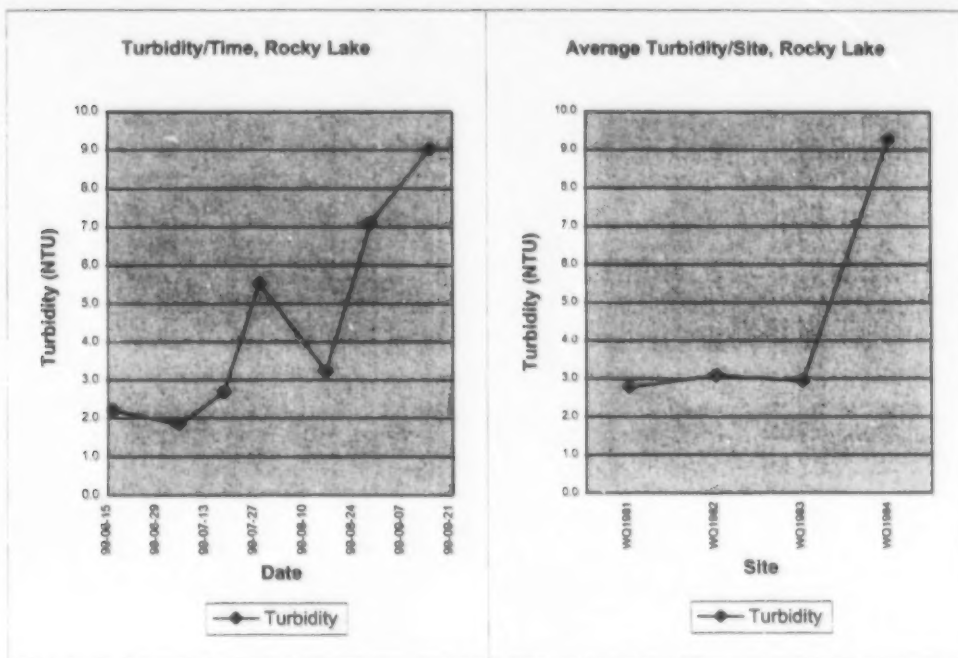


Figure 4. Average turbidity over time and at each site, Rocky Lake 1999.

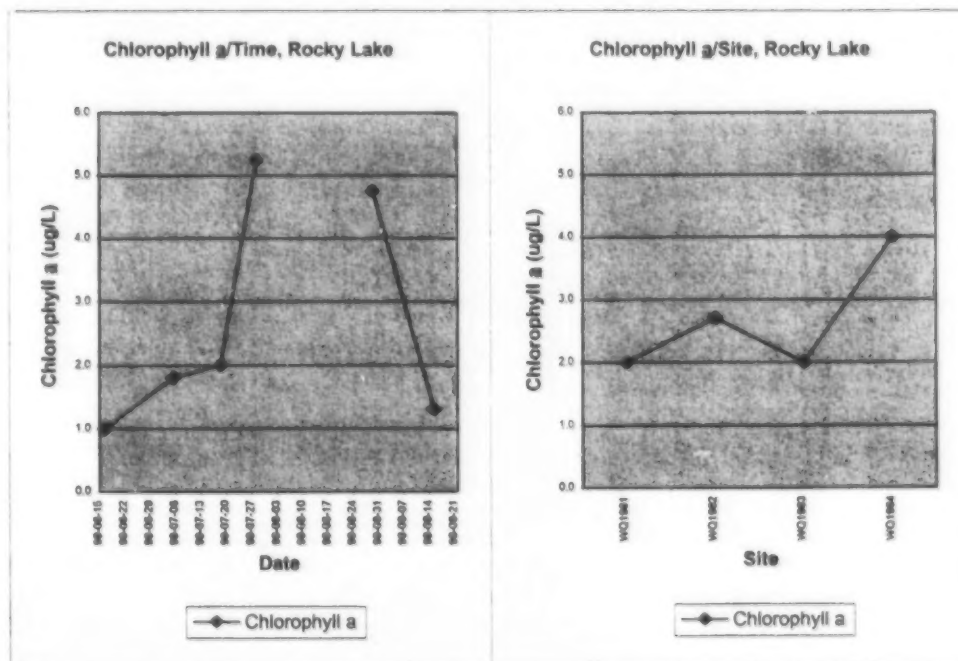


Figure 5. Average chlorophyll a over time and at each site, Rocky Lake 1999.

objective to protect drinking water of 10 mg/L. Un-ionized ammonia concentrations were also low with an overall average of 0.00132 mg/L in Rocky Lake. Un-ionized ammonia concentrations were well below calculated water quality objective levels in all cases. Objectives for un-ionized ammonia objectives relate to the protection of aquatic life and vary depending on temperature and pH.

Turbidity

Turbidity rises with increases in suspended particulate material (total suspended solids). The average turbidity in Rocky Lake was relatively low at 4.5 NTU. The average turbidity ranged from 2.8 to 3.1 NTU in the northeast basin while the average turbidity in the southwest basin was three times that at 9.3 NTU (Table 1 and Figure 3). The Secchi disk transparency provides a visual estimate of water clarity and the average Secchi disk transparencies for Rocky Lake were 1.86 to 2.00 m in the northeast basin that would indicate moderate to good water clarity, and 1.13 in the southwest basin indicating only moderate water clarity.

In Rocky Lake, turbidity rose abruptly on July 28 probably due to high winds, dropped on August 18 when wind speeds were light, and subsequently rose on August 29 to peak on September 15, 1999 when wind speeds were 15 to 25 km/h (Figure 3). As indicated in the discussion of total phosphorus, increases in turbidity probably occurred largely due to wind and wave action and possibly boating activity re-suspending particulate materials from bottom sediments in Rocky Lake. This was most prevalent at the shallow site WQ1984 in the southwest basin. Turbidity at site WQ1984 was significantly higher ($\alpha = 0.05$) than at any of the three sites in the northeast basin. There were no significant differences in turbidity between sites in the northwest basin.

Chlorophyll *a*

Except for June 16, 1999 where samples were collected at the surface and a metre off the bottom at each site chlorophyll *a* was analyzed from samples collected through the water column within the euphotic zone. A depth of twice the Secchi disk depth is the approximate depth of the euphotic zone, or zone of light penetration where algae photosynthesis can occur. Chlorophyll *a* was extracted from the algae in the water samples. The chlorophyll *a* concentrations were low to moderate in Rocky Lake with a relatively low average of < 2.0 to 2.7 $\mu\text{g/L}$ per site in the northwest basin with a slightly higher average of < 4.0 $\mu\text{g/L}$ at site WQ1984 in the southwest basin (Table 1 and Appendix 1).

Chlorophyll *a* in Rocky Lake corresponded with increases in total phosphorus and turbidity until the temperature declined in mid-September (Table 1 and Figures 2, 4, and 5). Although the highest total phosphorus and turbidity were noted on September 15, 1999 an average temperature drop of nearly 4°C appeared to limit algal growth.

Fecal Coliform Bacteria

Fecal coliform bacteria counts were < 10 organisms/100 mL of water in all but two samples from Rocky Lake over the summer of 1999. The other two samples were only slightly above detection limits at 10 and 20 organisms/100 mL (Appendix 1). This fecal coliform count was likely related to waterfowl or wildlife and would not have been related to any sewage discharges since this site is the most upstream site from the developed area. All the fecal coliform bacteria counts were well-below the recommended objective for recreational water quality of 200 organisms/100mL (Williamson 1988). However, as with all surface waters, if water from the lake is used as a domestic water source it should always be boiled or disinfected before it is used for drinking.

pH

During the summer of 1999 the pH values in Rocky Lake ranged from 8.61 and 8.90 (Appendix 1). The pH values were within the objective range of 6.5 and 9.0 recommended for the protection of aquatic life (Williamson 1988). The average pH values in northeast basin of Rocky Lake were 8.66 at both sites WQ1981 and WQ1982 in the main part of the basin, and 8.71 at site WQ1983 at the entrance to the channel to the southwest basin (Table 1 and Figures 1 and 6). The average pH value in the southwest basin was 8.77.

There were no significant differences in pH values between sites WQ1981 and WQ1982 or between sites WQ1983 and WQ1984 ($\alpha = 0.05$). However, the pH was significantly higher at sites WQ1983 and WQ1984 relative to sites WQ1981 and WQ1982. It appears, therefore, that site WQ1983 in the northeast basin may receive some influence from the water in the southwest basin.

Specific Conductivity

Specific conductivity is a measure of the dissolved salts in water and is closely related to total dissolved solids. During the summer of 1999 the conductivity in Rocky Lake ranged from 365 to 429 $\mu\text{S}/\text{cm}$ (Appendix 1). These were well below the recommended objective of 1000 $\mu\text{S}/\text{cm}$ (Williamson 1988). The average conductivities in the northeast basin of Rocky Lake were 426, and 425 $\mu\text{S}/\text{cm}$ at sites WQ1981, WQ1982, respectively, in the main part of the basin, and 420 $\mu\text{S}/\text{cm}$ WQ1983, at the entrance to the channel to the southwest basin (Table 1, and Figures 1 and 7). The average conductivity at site WQ1984 in the southwest basin was considerably lower at 376 $\mu\text{S}/\text{cm}$.

There were no significant differences in conductivity between sites WQ1981 and WQ1982 in the main part of the northeast basin but there was a significant decrease in conductivity between these sites and sites WQ1983 and WQ1984 ($\alpha = 0.05$). There was also a significant decrease in conductivity between site WQ1983 at the entrance to the channel to the southwest basin and the southwest basin site WQ1984 (Figure 1). It appears likely that the streams entering the southwest basin have a considerable influence on conductivity and that this influence would extend through the channel between the basins. As with pH, site WQ1983 appeared to be influenced to some degree by water from the southwest basin.

Water Quality on June 16, 1999

Results for all 83 variables measured in water samples collected on June 16, 1999 are shown in Tables 3 and 4 for Rocky Lake. Of these, 25 variables were used to calculate the water quality indices for Rocky Lake. Variables used in this index included total phosphorus, un-ionized ammonia, fecal coliform bacteria, pH and specific conductivity that have already been discussed. The following is a discussion of other variables that were also used.

Total suspended solids in Rocky Lake on June 16, 1989 (Table 2) were all $< 5 \text{ mg}/\text{L}$ and well below the objective of 25 mg/L (Williamson 1988). It is unlikely that suspended solids would have exceeded the objective since except for a few occasions at Site WQ1984 in the southwest basin where occasional moderate turbidity values were encountered the turbidity was generally relatively low throughout the summer (Appendix 1).

Dissolved oxygen is essential to the survival of fish stocks. Dissolved oxygen saturation levels should be 47% or higher for the maintenance of cool water aquatic life (Williamson 1988). All dissolved oxygen values were above this objective. The average dissolved oxygen concentration in

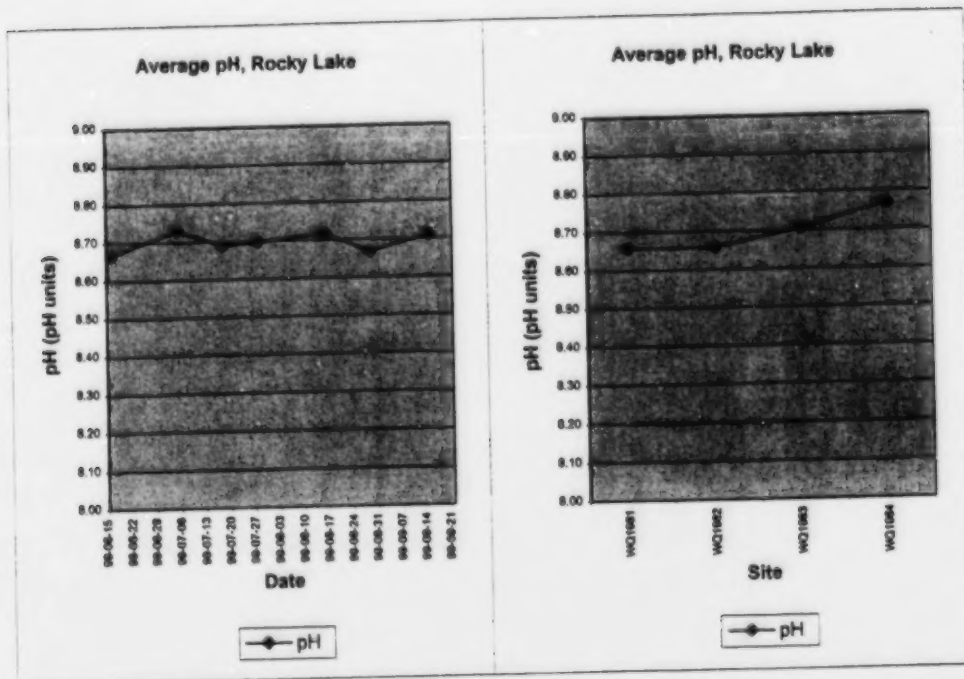


Figure 6. Average pH over time and at each site, Rocky Lake 1999.

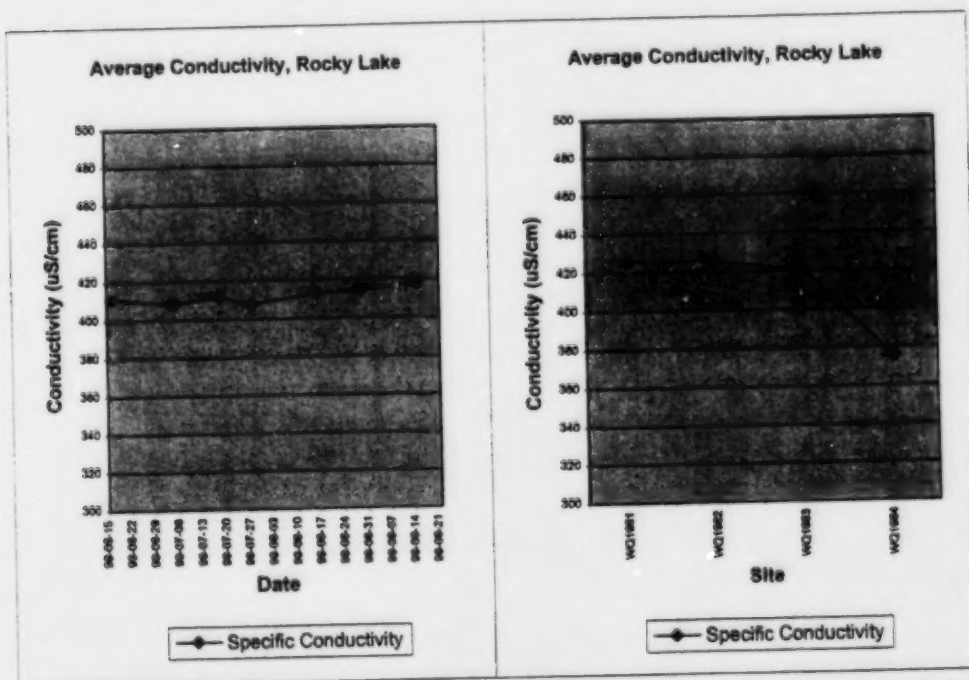


Figure 7. Average specific conductivity over time and at each site, Rocky Lake 1999.

Rocky Lake was 10.3 mg/L (Table 2). The water was fully saturated or in some cases super saturated with oxygen, as dissolved oxygen saturation levels were 97% or better, on June 16, 1999.

Trace metal analyses from water samples collected from Rocky Lake on June 16, 1999 included total concentrations of cadmium, copper, nickel, lead, and zinc, and arsenic and dissolved aluminum. In Rocky Lake, the total cadmium, copper, and lead concentrations were all below detection limits while total nickel, zinc, and arsenic concentrations were frequently below detection limits (Tables 2). All these metals were below their respective objectives (Williamson 1988). The objective for aluminum is dependent on pH and in all cases the objective was 0.1 mg/L. There were no exceedences of the dissolved aluminum objective in Rocky Lake.

Iron and manganese are of an aesthetic concern in drinking water but can be removed with treatment. These two metals were well below the recommended objective for iron of 0.3 mg/L and the recommended objective for manganese of 0.05 mg/L (Williamson 1988).

Pesticide analyses conducted on water samples collected from Rocky Lake on June 16, 1999 indicated that all 39 pesticides were less than the detection limits (Tables 3 and 4). Although Mimic (Tebufenozide), a pesticide had recently been sprayed in the area for the control of spruce budworm it was not detectable.

The water quality index for Rocky Lake was based on 25 variables that have been previously discussed. The index used in this case is the Canadian Water Quality Index (CWQI). Table 3 shows the CWQI rating for Rocky Lake as well as three other northern Manitoba lakes including Paint, Liz, and Clearwater lakes. These indices indicated "Excellent" water quality for all four lakes with CWQI falling in the range of 85 to 100. Rocky Lake rated at 97. The only lake that rated at a higher score was Liz Lake for 1998, where there were no exceedences of objectives that resulted in a perfect CWQI of 100.

A water quality index rating of "Excellent" indicates that:

- all water uses are protected, with a virtual absence of impairment or only a minimal degree of impairment,
- no water uses are ever interrupted and,
- conditions rarely depart from desirable quality.

Table 3. Comparisons of water quality in Rocky, Clearwater, Paint and Liz Lakes using a revised Canadian Water Quality Index (CWQI).

Lake	Year	CWQI	Category*	Notes
Rocky Lake	1999	97	Excellent	Index used 25 variables.
Clearwater Lake	1996	87	Excellent	Index used 25 variables.
Clearwater Lake	1989	95	Excellent	Index used 16 variables no pesticides or aluminum.
Paint Lake	1998	93	Excellent	Index used 25 variables.
Liz Lake	1998	100	Excellent	Index used 25 variables.

* Category ranges: 85-100 Excellent; 70-84 Good; 55-69 Fair; 40-54 Marginal; 0-39 Poor

The CWQI is based on a modified version of a water quality index for agricultural streams in Alberta (Wright *et al* 1998).

$$CWQI = 100 - (((F_1^2 + F_2^2 + F_3^2)^{1/2}) / 1.732)$$

$$F_1 = ((\text{Number of variables with an objective not met}) / (\text{Total number of variables})) \times 100$$

$$F_2 = ((\text{Number of samples with an objective not met}) / (\text{Total number of samples})) \times 100$$

$$F_3 = ((amp) / (0.01amp + 0.01))$$

Where *amp* is the normalized sum of test departures:

$$amp = (\text{Sum of departures}_i) / (\text{Number of tests})$$

Where test values must not exceed the objective:

$$\text{departure}_i = (\text{Concentration}_i) / (\text{Objective}_i)$$

Where test values must not fall below the objective:

$$\text{departure}_i = (\text{Objective}_i) / (\text{Concentration}_i)$$

Where the objective is zero:

$$\text{departure}_i = \text{Concentration}_i$$

CONCLUSIONS

Rocky Lake is comprised of two main basins, a relatively deep northeast basin where resort and cottage development have taken place and a shallow undeveloped southwest basin. Differences in water quality between the basins are due in part to differences in depth and in part to the influence of inlet streams on the southwest basin. Overall, the water quality in Rocky Lake was excellent.

- maintained excellent bacteriological characteristics but, as with all surface waters, lake water should always be boiled or disinfected before use for drinking water;
- trace metal concentrations were very low or below detection limits;
- pesticide concentrations were below detection limits;
- dissolved oxygen concentrations were excellent;
- although total nitrogen increased over the summer, un-ionized ammonia and nitrate-nitrite nitrogen remained low and well below water quality objectives;
- dissolved phosphorus concentrations were fairly low and remained relatively stable throughout the summer of 1999;
- total phosphorus concentrations were generally low but exceeded water quality objectives from end of July through to mid-September, 1999. Total phosphorus was significantly higher in the shallower southwest basin. It appears that particulate phosphorus was added to the water column due largely to wind and wave action stirring up bottom sediments;
- turbidity was higher on windy sampling days that occurred at the end of July, at the end of August and in mid-September. The shallower southwest basin was significantly more turbid and subsequently produced higher total phosphorus values than were noted in the northeast basin;
- chlorophyll *a* extracted from algae was generally low in the deeper northeast basin but somewhat higher in the southwest basin where phosphorus was more available. Although total phosphorus was the highest in September 1999, there was a decline in algae growth due to lower temperatures;
- the pH was significantly higher in the southwest basin than in the northeast basin;
- the conductivity was significantly lower in the southwest basin than in the northeast basin possibly due to dilution from water entering the southwest basin from inlet creeks;
- although there were differences in water quality between the northeast and southwest basins, the overall water quality index (CWQI) rated the water quality in Rocky Lake as "Excellent".

ACKNOWLEDGMENTS

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Appendix 1



Appendix 1. All chemical, physical and biological variables (excluding extra variables for which analyses were performed on water samples collected on June 16, 1996*), Rocky Lake, 1999

Site	Sample Date	Temperature °C	Fecal Coliform Bacteria/100mL	pH	Specific Conductivity uS/cm	Turbidity NTU	Secchi Disk Depth m	Total Ammonia mg/L	Un-ionized Ammonia mg/L	Nitrate-Nitrite mg/L	Total Kjeldahl Nitrogen mg/L	Total Phosphorus mg/L	Particulate Phosphorus mg/L	Dissolved Phosphorus mg/L	Chlorophyll a ug/L
WQ1981	1999-06-16 Surface	18.0	< 10	8.61	428	1.9	2.90	0.010	0.00149	< 0.01	0.40	0.017	0.009	0.008	< 1
WQ1981	1999-06-16 Bottom	17.0	< 10	8.61	428	1.5	---	0.004	0.00056	< 0.01	0.40	0.020	0.012	0.008	< 1
WQ1982	1999-06-16 Surface	18.0	< 10	8.63	428	1.5	3.40	0.008	0.00124	< 0.01	0.40	0.016	0.009	0.007	< 1
WQ1982	1999-06-16 Bottom	17.0	< 10	8.63	426	2.0	---	0.002	0.00029	< 0.01	0.40	0.021	0.013	0.008	< 1
WQ1983	1999-06-16 Surface	17.0	< 10	8.65	417	1.8	2.70	< 0.001	0.00015	< 0.01	0.50	0.019	0.011	0.006	< 1
WQ1983	1999-06-16 Bottom	18.0	< 10	8.68	412	1.6	---	0.003	0.00051	< 0.01	0.50	0.022	0.013	0.009	1
WQ1984	1999-06-16 Surface	17.0	< 10	8.78	373	3.6	1.60	0.004	0.00075	< 0.01	0.80	0.020	0.014	0.008	1
WQ1984	1999-06-16 Bottom	17.0	< 10	8.76	374	3.6	1.60	< 0.001	< 0.00019	< 0.01	0.70	0.021	0.013	0.008	1
WQ1981	1999-07-05 Bottom	18.0	< 10	8.95	425	1.4	1.60	0.004	0.00084	< 0.01	0.80	0.014	---	0.007	1
WQ1982	1999-07-05 Bottom	18.0	< 10	8.84	423	1.6	1.60	0.009	0.00142	< 0.01	0.80	0.020	---	0.009	2
WQ1983	1999-07-05 Bottom	18.0	< 10	8.73	416	1.4	1.90	0.009	0.00170	< 0.01	0.70	0.013	---	0.008	2
WQ1984	1999-07-05 Bottom	19.0	< 10	8.90	369	3.0	1.25	0.004	0.00110	< 0.01	0.80	0.021	---	0.008	2
WQ1981	1999-07-18 Bottom	20.0	< 10	8.62	427	1.6	2.50	0.006	0.00103	< 0.01	0.80	0.022	0.015	0.007	2
WQ1982	1999-07-18 Bottom	20.0	< 10	8.62	426	1.7	2.50	0.003	0.00052	< 0.01	0.70	0.021	0.013	0.008	2
WQ1983	1999-07-18 Bottom	20.0	< 10	8.66	422	1.7	2.25	0.005	0.00093	< 0.01	1.00	0.018	0.011	0.007	2
WQ1984	1999-07-18 Bottom	20.0	< 10	8.86	372	5.5	1.75	0.003	0.00081	< 0.01	1.00	0.021	0.014	0.007	2
WQ1981	1999-07-28 Bottom	---	< 10	8.65	424	3.4	---	0.002	---	< 0.01	0.70	0.024	0.015	0.009	3
WQ1982	1999-07-28 Bottom	---	< 10	8.67	423	3.0	---	0.005	---	< 0.01	0.70	0.023	0.014	0.009	6
WQ1983	1999-07-28 Bottom	---	< 10	8.73	418	2.7	---	0.010	---	< 0.01	0.90	0.023	0.014	0.009	2
WQ1984	1999-07-28 Bottom	---	< 10	8.74	395	13.0	---	0.003	---	< 0.01	1.10	0.038	0.028	0.007	10
WQ1981	1999-08-16 Bottom	20.0	< 10	8.68	429	2.0	2.00	0.010	0.00194	< 0.01	0.70	0.023	0.013	0.010	---
WQ1982	1999-08-16 Bottom	18.0	< 10	8.67	426	2.6	1.90	0.010	0.00168	< 0.01	0.80	0.030	0.023	0.007	---
WQ1983	1999-08-16 Bottom	20.0	< 10	8.72	423	3.5	1.80	0.006	0.00167	< 0.01	0.80	0.032	0.024	0.008	---
WQ1984	1999-08-16 Bottom	20.0	< 10	8.80	374	4.8	1.20	0.012	0.00292	< 0.01	0.90	0.028	0.021	0.007	---
WQ1981	1999-08-29 Bottom	18.0	< 10	8.69	422	4.0	2.00	0.020	0.00349	0.02	0.80	0.028	0.019	0.010	4
WQ1982	1999-08-29 Bottom	18.0	< 10	8.66	426	6.2	1.50	0.020	0.00329	< 0.01	0.80	0.031	0.020	0.011	4
WQ1983	1999-08-29 Bottom	19.0	< 10	8.70	424	4.2	1.50	0.010	0.00189	< 0.01	0.80	0.023	0.014	0.009	4
WQ1984	1999-08-29 Bottom	17.0	< 10	8.82	394	14.0	0.50	0.020	0.00284	< 0.01	1.10	0.040	0.027	0.013	7
WQ1981	1999-09-15 Bottom	15.0	20	8.70	426	5.1	1.00	< 0.002	< 0.00029	< 0.01	0.90	0.032	0.020	0.012	< 1
WQ1982	1999-09-15 Bottom	15.0	10	8.71	427	4.7	1.00	< 0.002	< 0.00030	< 0.01	1.00	0.028	0.016	0.011	1
WQ1983	1999-09-15 Bottom	15.0	< 10	8.73	425	5.3	1.00	< 0.002	< 0.00031	< 0.01	1.00	0.031	0.020	0.011	1
WQ1984	1999-09-15 Bottom	12.0	< 10	8.70	381	21.0	0.50	< 0.002	< 0.00024	0.01	1.50	0.047	0.030	0.017	2
Water Quality Objective															
200 6.5-6.0 1000															
Calculated No Exceedences															
10															
0.025															

* All data for water samples collected on June 16, 1999 is shown in Table 2.

Appendix 2

Synopsis of water chemistry variables that were detected or used in the water quality index.



Appendix 2. Synopsis of water chemistry variables that were detected or used in the water quality indices.

Summary and Interpretation of Aquatic Variables

Introduction

The following provides a brief synopsis of the water quality variables analyzed. The variables are listed alphabetically by name for quick reference. Each variable name is followed immediately by the units of measure in that it is most commonly reported. Also after each variable name is its chemical symbol or formula (in the case of compounds), and in most cases, the most commonly encountered ionized form of the variable in water. A short discussion of the uses, biological importance, potential sources, and general water chemistry of each variable is then summarized.

Each variable summary is concluded by a table of guidelines and objectives that have been established for maximum acceptable concentrations of the variable in water. These guidelines and objectives are helpful in that they allow one to determine if the water quality of a surface supply is adequate and safe for its intended use. Manitoba Surface Water Quality Objectives (**MSWQO**) are specific to the Manitoba situation, and define objectives for raw water sources that, if followed, will ensure that the water supply remains suitable for its intended use with only minimal need for treatment. Guidelines for Canadian Drinking Water Quality (**GCDWQ**) specify the conditions that affect the quality of water intended for domestic use (drinking and household uses) and are useful in determining if a treated drinking water supply (i.e. treated tap water) is suitable for human consumption, or requires further refining. Canadian Water Quality Guidelines (**CWQG**) and **MSWQO** for aquatic life, irrigation, and livestock consumption are used to assess the suitability of a water supply for the maintenance of aquatic organisms, crop irrigation, and livestock watering. Depending on the variable, livestock guidelines and objectives are often presented as a range of values because of the variation in sensitivity between different types and ages of livestock. Ranges in **CWQG** and **MSWQO** for irrigation water indicate that the guidelines and objectives vary depending on the type of crop and soil present. Generally the lower end of the range for each objective/guideline applies to greenhouse and vegetable crops, that are usually more sensitive (less tolerant) than cereal crops. Guidelines for Canadian Recreational Water Quality (**GCRWQ**) specify conditions suitable for primary and secondary recreational uses such as swimming, boating, skiing, etc. The **MSWQO** for recreation presented here are only for primary recreational recreation use, that includes full contact activities such as swimming, skiing, wading, etc.

In this document, water quality objectives apply to the raw water supply, while the guidelines apply to water at the point of use; that can range from treated domestic tap water, to raw water used for irrigation and livestock watering.

Alkalinity (mg/L)

Alkalinity is an indication of the buffering capacity of the water, that is the ability of the water to neutralize acid inputs. Alkalinity is usually reported as total alkalinity (CaCO_3), bicarbonate alkalinity (HCO_3), carbonate alkalinity (CO_3), and hydroxide alkalinity (OH). Although high alkalinity itself is not considered to be harmful, it is usually associated with high pH and high water hardness, and excessive dissolved solids.

Alkalinity (total) (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline					
Objective	30 - 500 (A)	1000			

(A) = Guideline or objective based on aesthetic considerations.

Ammonia (mg/L) (NH_3 and NH_4^+)

Ammonia is an inorganic form of nitrogen that can be used directly for use by plants. Nitrogen itself is one of the three main macro-nutrients required by plants, and inadequate levels of a usable form of nitrogen in soil or water can severely limit plant growth and development. Natural sources of ammonia in surface waters include the decomposition of plant material and animal wastes, gas exchange with the atmosphere (pure ammonia being a gas and present in air), weathering of clays, and nitrogen fixation by micro-organisms. Ammonia is a major component in soil fertilizers and significant amounts can enter surface water supplies in run-off from cultivated fields. This can promote excessive growth of algae and other aquatic plants. Ammonia is found in water as NH_3 (its un-ionized form) and as NH_4^+ (its ionized form called ammonium). In water the two forms (NH_3 and NH_4^+) exist in equilibrium and their combined concentration is referred to as total ammonia. This equilibrium is dependent on water pH and temperature, with high pH and temperature causing a shift from $\text{NH}_4^+ \rightarrow \text{NH}_3$, and low pH and temperature favoring a shift from $\text{NH}_3 \rightarrow \text{NH}_4^+$. In the presence of sufficient dissolved oxygen, ammonia breaks down to form nitrate and nitrite, two forms of nitrogen that are also readily taken-up by plants. The toxicity of ammonia in surface waters is related to the total amount of ammonia present, and in particular the ratio of $\text{NH}_3:\text{NH}_4^+$. Ammonia in domestic drinking water is not a problem for humans, however, temperature and pH dependent Manitoba water quality objectives have been established for fish and other aquatic life.

Ammonia (mg/L N)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline			1.37 - 2.2 *		
Objective			0.0184 - 0.05 **		

* Guideline/objective changes with pH and temperature. Values refer to total ammonia.

** Guideline/objective changes with pH and temperature. Values refer specifically to unionized ammonia.

Arsenic (mg/L) (As^{+3} and As^{+5})

Arsenic is a metalloid (metal-like) element that is sometimes present in surface water in trace amounts. The main source of arsenic in surface water is weathering of igneous and sedimentary rocks that contain arsenic. The amount of arsenic in surface waters varies from place to place in accordance with underlying geological formations. Human sewage, industrial effluents, and pesticide run-off also contribute a significant amount of arsenic to surface waters. Arsenic has a relatively complex chemistry in water. Various forms or compounds of arsenic can be present, with certain forms being more chemically reactive than others. In large concentrations arsenic can be toxic to plant and animal life. It has been shown to accumulate in certain aquatic organisms, and thus chronic exposure to lower concentrations may also cause problems.

Arsenic (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.025 (H)	0.5 - 5.0	0.05	0.1	
Objective	0.05 (H)	0.5	0.19	0.1 - 2.0	

(H) = Guideline or objective based on health considerations.

Atrazine ($\mu\text{g/L}$) ($\text{C}_8\text{H}_{14}\text{ClN}_5$)

Atrazine (2-chloro-4-ethylamino-6-isopropylamino-1,2,3-triazine) is an organonitrogen herbicide used extensively across Canada as a mechanism for pre- and post-emergent weed control, primarily in corn and canola crops. It is further used to control weeds on non-cropland and industrial areas, and has had success in silviculture (forestry) applications. Atrazine is distributed under a number of trade names in Canada, including: Aatrex®; Calmix® 5; Chipman® Atrazine Flowable; Co-op® Atrazine 90W Herbicide; Niagara® Liquid Atrazine; Primextra®; Shell® Atrazine 90W; and Shell® Blazine Liquid Herbicide. Atrazine enters the aquatic environment through production, accidental spillage, use, and disposal. It has been estimated that approximately 1% of the atrazine applied to agricultural land enters nearby surface water supplies as a result of field run-off. Atrazine is removed from water via microbial and chemical degradation. Little information is available with regard to the role of water chemistry in the breakdown of this herbicide and the rate at which it occurs. Atrazine has been classified as being potentially carcinogenic to humans.

Atrazine ($\mu\text{g/L}$)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
CWQG	5 (H)	60	2	10	
MSWQO					

(H) = Guideline or objective based on health considerations.

Boron (mg/L) (B)

Boron is a metalloid (metal-like) element essential, in trace amounts, for flower and fruit development, and hormone movement in plants. It is presently not considered a necessary element in the diet of humans. Weathering of igneous and sedimentary rocks, and leaching of soil all contribute boron to surface waters. Boron has a wide variety of uses in the chemical industry. Perhaps most notably, it is an ingredient in borax, a domestic and industrial cleaning compound and water softener, and as such can readily be passed into surface waters through effluent drainage. Boron occurs in water as the borate ion ($\text{B}(\text{OH})_4^-$) and as weak boric acid salt (H_3BO_3). However, because boric acid has low solubility in water, the tendency for disassociation is also low and free boron ions (B^{+3}) are rare. Boron toxicity can occur at high concentrations, leading to diarrhea, headaches, vomiting, kidney problems, and possibly sterility. Boron concentrations in surface waters in Canada generally fall below 0.5 mg/L.

Boron (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	5.0 (H)	5.0		0.5 - 6.0	
Objective	5.0 (H)	5.0		0.5 - 2.0	

(H) = Guideline or objective based on health considerations.

Bromoxynil ($\mu\text{g/L}$) ($\text{C}_7\text{H}_3\text{Br}_2\text{NO}$)

Bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) is the common name for a group of phenoxy-acid herbicides containing bromine. It is one of the most commonly used herbicides on the Canadian prairies. It is used for the control of broad-leaved vegetation in grain crops. Bromoxynil is also often used in combination with other herbicides such as MCPA, diclo-methyl, and dicamba. The types of bromoxynil herbicides used in Canada tend to adhere strongly to soil and vegetation particles, thus limiting leaching and run-off into ground or surface waters. Bromoxynil can, however, enter surface waters through accidental spills, improper disposal and clean-up, and aerial spray drift. Bromoxynil herbicides appear to be broken down quite rapidly in water. The rate of degradation is dependent on water pH, temperature, and exposure to sunlight. Research has demonstrated that the herbicide has

moderately high acutely toxic effects on the liver, but has not been shown to be carcinogenic in animals. Activated charcoal filtration appears to be effective in removing bromoxynil from drinking water.

Bromoxynil (µg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	5 (H)	11	5	0.35	
Objective					

(H) = Guideline or objective based on health considerations.

Cadmium (mg/L) (Cd⁺²)

Cadmium is a metallic element found in small amounts in the earth's crust; usually associated with zinc, lead, and copper ores. Cadmium has a number of industrial applications such as metal plating, and is an important ingredient in nickel-cadmium storage batteries, solders, and electrical equipment. Pathways into surface water include weathering of cadmium containing igneous rocks and shales, emissions and effluent from the mining industry, run-off from agricultural lands (found in some pesticides), and the burning of fossil fuels. In general only trace amounts (< 0.001 mg/L) of cadmium are found in surface water supplies. The form, chemistry, and solubility of cadmium in surface water is complex and is influenced by pH, hardness (calcium and magnesium), and the presence of other metal ions. Food is the main source of cadmium intake by humans. Chronic long-term exposure to cadmium can cause gastrointestinal problems, bone deterioration, and kidney disease. There have been no concrete links made between cancer in humans and cadmium consumption, however, research into this area continues. Because cadmium is found in food, it is important to minimize the amount ingested through drinking water, and thus minimize the total cadmium in one's diet.

Cadmium (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.005 (H)	0.02	0.0002 - 0.0018*	0.01	
Objective	0.005 (H)	0.02	0.00066 - 0.002*	0.01	

(H) = Guideline or objective based on health considerations.

* Guideline/objective changes with hardness.

Calcium (mg/L) (Ca⁺²)

Calcium is often the most abundant dissolved element in surface water supplies. This is due to its abundance on the earth's surface (it is a major constituent of limestone rock) and the fact that it is readily dissolved from rocks and leached from the soil by water. Calcium is essential for bone growth and maintenance in vertebrates and cell wall and cell membrane structure in plants. When dissolved in water calcium exists as the calcium ion (Ca⁺²). This calcium ion is strongly electropositive and easily attracts negatively charged ions to form salt compounds (e.g.: calcium carbonate CaCO₃) that precipitate out of solution. This activity is enhanced by high water temperatures. Thus, in most instances the concentration of calcium ions in solution tends to decrease during the summer and increase in the fall and winter. Levels of calcium in surface waters of western Canada range from 0.28 to 67.0 mg/L. There is no established guideline or water quality objective for maximum acceptable calcium concentration in human drinking water. The only guideline at present is for livestock and is established at 1000 mg/L. High levels of calcium, in company with magnesium, contribute to increased hardness of the water and high pH values.

Carbon, Total (mg/L) (C)

Carbon is the most common element in all living organisms. Along with hydrogen and oxygen it forms carbohydrates (sugars, starch, cellulose) that account for up to 96% of the dried weight of plant material. Total carbon is the sum of all inorganic and organic forms of carbon in the water. Carbon sources in water include decaying plant and animal material, effluent from industry, human sewage, agricultural run-off, weathering of carbonate rock, plant and animal respiration, and gas exchange with the atmosphere. Presently there are no guidelines or objectives for total carbon in surface water.

Carbon, Total Inorganic (mg/L) (C)

Total inorganic carbon (TIC) is a measure of the amount of carbon present in inorganic compounds in water. Some of the major inorganic carbon compounds in water include carbonates (e.g.: calcium carbonate - CaCO_3), bicarbonates (e.g.: sodium bicarbonate NaHCO_3), and carbonic acid (H_2CO_3). These inorganic carbon compounds usually dissolve quite readily in water and have a strong influence on water hardness, pH, and alkalinity. Sources of inorganic carbon include weathering of limestone and dolomite rock that contain magnesium and calcium carbonates, and carbon dioxide from respiring organisms and the atmosphere. Presently there are no guidelines or objectives for TIC in surface water.

Carbon, Total Organic (mg/L) (C)

Total organic carbon (TOC) refers to the amount of carbon in organic material in the water, and as such is an overall indicator of the organic content of the water. TOC can occur in both dissolved and particulate forms. The main sources of TOC in surface waters are photosynthesis and decaying plant and animal tissue. Domestic sewage, effluent from certain industries (e.g.: pulp and paper), and agricultural run-off can also contribute organic carbon to surface waters. Concentrations of TOC in water are affected by shoreline erosion, plant productivity, and the specific composition of the organic material (the amount of carbon depending on the type of material present). At present there are no guidelines or objectives for TOC in surface water. However, steps should be taken to reduce levels as much as possible as the amount of TOC in water has a direct effect on the amount of oxygen in the water. Dissolved oxygen is consumed as organic material is decomposed. Thus, water high in TOC concentrations can become anaerobic (oxygen depleted), that can affect fish and other aquatic organisms, as well as create taste and odour problems. Artificial aeration of the water can help to alleviate this problem. High organic carbon concentrations have also been linked to increased formation of trihalomethanes in water disinfected with chlorine.

Chloride (mg/L) (Cl^-)

Chloride is the negatively charged ion of chlorine. Chlorine is an essential element for both animal and plant life. In combination with positively charged ions, chloride forms such salts as sodium chloride (common table salt), potassium chloride (potash), and calcium chloride (road salt). The relatively high water solubility of chloride salts make them important and useful substances for the chemical and agricultural industry. Concentrations of chloride in surface waters are usually <10 mg/L under natural conditions. However, chlorides usually increase with the use of chlorine as a disinfectant or bleaching agent, and with the use of water softening salts. As well, saline groundwater intrusion may occur in certain areas. High chloride levels in drinking water are not considered a health concern, but may result in taste problems and can adversely affect sensitive aquatic plant species.

Chloride (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	250 (A)			100 - 700	
Objective	250 (A)			68 - 150	

(A) = Guideline or objective based on aesthetic considerations.

Chromium (mg/L) (Cr⁺⁶ (hexavalent chromium or chromium (VI)))

Chromium is a white, lustrous, hard metal that is very resistant to corrosion. This makes it very useful as a protective and decorative coating for other metals such as brass, bronze, and steel. It is also used extensively in the production of paints, dyes, explosives, ceramics, and paper, and in some fertilizers and pesticides. Major pathways for chromium into surface water include the weathering of chromium minerals such as chromite (FeCr₂O₂), and industrial emissions. Chromium can exist in a number of ionic states in water, but chromium (III) (trivalent chromium - Cr⁺³) and chromium (VI) (hexavalent chromium - Cr⁺⁶) are the most common. Chromium (III) is actually considered an essential element for protein, sugar, and lipid metabolism in humans and other animals. Because of this it is considered non-toxic, but can, in water, be converted to the toxic chromium (VI), if the water is chlorinated. Research has yet to show a clear link between cancer and chromium intake. However, prolonged exposure to chromium (VI) can cause gastrointestinal, liver, and kidney problems. Laboratory analysis is concerned with determining the concentration of chromium(VI) because it is the toxic form of the element in water. Concentrations in Canadian surface waters are generally low; ranging from <0.001 to 0.044 mg/L for total chromium, and <0.001 to 0.023 mg/L for chromium (VI).

Chromium (VI) (hexavalent) (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.05 (H)	1.0	0.002 - 0.02	0.1	
Objective	0.05 (H)	1.0	0.011	0.1 - 1.0	

(H) = Guideline or objective based on health considerations.

Coliform Bacteria, Fecal (fecal coliform units/100 ml)

Fecal coliforms are a group of bacteria comprised of *Escherichia coli* (more commonly referred to as *E. coli*) and species of the genus *Klebsiella*. Both *E. coli* and *Klebsiella* spp. occur naturally in the intestinal tract of birds and mammals. *Klebsiella* spp. may also be found in organic-rich effluents such as those from pulp and paper operations. Fecal coliforms are important because they can indicate the presence of other disease-producing organisms. High numbers of fecal coliform bacteria in water generally indicates the presence of undisinfected fecal matter. Sources of fecal coliform bacteria include feces from humans, livestock, and wildlife. The presence of fecal coliform bacteria is considered unacceptable in drinking water. As with total coliforms, fecal coliform levels in drinking water can usually be controlled by disinfection methods. Lab results of <10/100 ml indicate no fecal coliforms were found in the water samples.

Fecal Coliform Bacteria (number/100 ml)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.0 (H)			100	
Objective	10.0 (H)	minimize		1000	200

(H) = Guideline or objective based on health considerations. Domestic consumption guideline refers to treated water.

Colour (True Colour Units)

The primary concern for colour in drinking water is one of aesthetics. Colour itself is not harmful, but high values are considered aesthetically unpleasant, and are indicative of excessive levels of organic matter and/or metals (e.g. iron, manganese, and copper).

Colour (True Colour Units)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	15 (A)				
Objective	15 (A)				

(A) = Guideline or objective based on aesthetic considerations.

Conductivity ($\mu\text{S}/\text{cm}$)

Conductivity is an indirect measure of the dissolved salt or mineral content in the water. Conductivity is measured by passing an electrical current through the sample. The higher the concentration of dissolved materials in the water, the higher the electrical conductivity. Thus, conductivity is very low in distilled water, and high in saline, alkaline, and hard water. There are presently no domestic consumption guidelines or objectives for conductivity.

Conductivity ($\mu\text{S}/\text{cm}$)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline				1500 - 2000	
Objective		4300		1000 - 2000	

Copper (mg/L) (Cu^{+2})

Copper is a metallic element that can occur in nature in pure form, but is more often found associated with other metals in mineral complexes. It is an essential element for certain enzymatic processes in plants and animals. Copper is used extensively in the production of electrical wire, piping, and numerous metal alloys. It is also an important constituent in pesticides used to protect and preserve wood and to control algae and other plant growth in water supplies used for drinking. Weathering of rocks and minerals, corrosion of brass and copper pipes, run-off from cultivated fields, the use of copper compounds as algicides, and sewage plant and mining effluents are the most common pathways for copper into surface water supplies. In non-polluted surface waters in Canada copper concentrations rarely exceed $0.05 \text{ mg}/\text{L}$. The chemistry of copper in water is very complex and not fully understood. Generally if present in water it is as the cupric ion (Cu^{+2}). However, the concentration of these ions is strongly influenced by water pH. At pH levels above 6.5, cupric ions tend to precipitate out of solution as $\text{Cu}(\text{OH})_2$ or combine with carbonates, oxides, and sulphides to form colloidal suspensions or precipitates. High concentrations of copper can lead to corrosion of zinc and aluminum, staining of laundry and bathroom fixtures, and may impart a bitter taste to drinking water. Copper is toxic to humans only at very high concentrations.

Copper (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	1.0 (A)	0.5 - 5.0	0.002 - 0.004 *	0.2 - 1.0	
Objective	1.0 (A)	1.0	0.0065 - 0.021 *	0.2 - 5.0	

(A) = Guideline or objective based on aesthetic considerations.

* Guideline/objective changes with hardness.

2,4-D ($\mu\text{g/L}$) ($\text{C}_8\text{H}_6\text{Cl}_2\text{O}_3$)

2,4-D ((2,4-dichlorophenoxy)acetic acid) is a phenoxy-acid herbicide used to control broadleaf weeds on cultivated land, pasture land, lawns, right-of-ways, and industrial property. It is also used in forestry to suppress the growth of undesired hardwood species and, in doing so, promotes the growth of conifers. 2,4-D has the same chemical formula as dicamba (another phenoxy-acid herbicide), but possesses a different molecular structure. There a large number of registered herbicide in that 2,4-D is an active ingredient. Some examples include Agrotect®, Aqua-Kleen®, Dacamine®, Esteron®, Killex®, Weedar®, and Weedone®. Agricultural run-off, aerial drift, direct application (to control vegetation along ditches and roadsides), accidental spills, indirect applications (i.e. over-spray of adjacent water bodies), and urban sewage are major sources of 2,4-D in surface waters. The herbicide has been detected at concentrations below 30 $\mu\text{g/L}$ (0.030 mg/L) in raw and treated drinking water supplies across the country. 2,4-D in water is degraded through hydrolysis (decomposition through interaction with water molecules), photolysis (exposure to sunlight and ultraviolet radiation), and microbial activity. Such factors as dissolved oxygen content (the higher the better), pH, clarity, and temperature of the water influence the rate of degradation of the herbicide. Current research has indicated that 2,4-D may be a carcinogen (cancer causing agent) in animals.

2,4-D ($\mu\text{g/L}$)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	100 (H)	100	4		
Objective	100 (H)				

(H) = Guideline or objective based on health considerations.

Dicamba ($\mu\text{g/L}$) ($\text{C}_8\text{H}_6\text{Cl}_2\text{O}_3$)

Dicamba (3,6-dichloro-o-anisic acid) is a widely used phenoxy-acid herbicide. Dicamba has the same chemical formula as 2,4-D (another phenoxy-acid herbicide), but the molecular structure of the two herbicides differs. Dicamba is a broad spectrum herbicide used for control of broadleaf weeds and woody perennials. In Canada pesticides containing dicamba are increasingly being used with other herbicides, such as bromoxynil and 2,4-D, for vegetation control in croplands, pastures, roadsides and right-of-ways, and forest plantations. Dicamba is sold as a liquid, but is also available in pellets and granules. In Canada it is sold under the trade names Banvel® Herbicide, Banvel® 720 Herbicide, and Dycleer® Herbicide. It is also an ingredient in Killex®, that is used extensively on lawns. Dicamba can enter surface waters through spills, aerial drift, improper disposal methods, and direct overspray of water bodies during application. Dicamba is very soluble in water and run-off from adjacent cropland is another pathway into the aquatic environment. Microbial degradation is the major way in that dicamba is broken down in water. Studies have shown that the half-life (time required for the concentration to be reduced by half) of dicamba in water is less than a week, but may vary depending on the various chemical and biological characteristics of the water body. Dicamba is a fairly low acute liver toxin. Granular activated charcoal is a potential method of removing dicamba from drinking water.

Dicamba ($\mu\text{g/L}$)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
CWQG	120 (H)	122	10	0.006	
MSWQO					

(H) = Guideline or objective based on health considerations.

Hardness (mg/L)

Hardness is a measure of the positively charged ions dissolved in water. Calcium (Ca^{+2}) and magnesium (Mg^{+2}) are the main contributors to water hardness because of their high concentrations in nature. High hardness values result from water draining through carbonate rock and other calcareous

materials that are high in calcium and magnesium. Water with hardness levels ranging from 0 to 30 mg/L is considered soft, while levels in excess of 180 mg/L are characteristic of very hard water. Hardness influences the form and toxicity of some heavy metals. Hard water can be treated with a softener, but this will result in elevated chloride and sodium or potassium levels in the water. A domestic surface water quality objective of 200 mg/L has been recommended in Manitoba based on aesthetic considerations. No other guidelines or objectives have been proposed.

Iron (mg/L) (Fe^{+2} , Fe^{+3})

Iron is the fourth most common element in the earth's crust. It is a heavy metal that is essential for photosynthesis in plants and production of hemoglobin in red blood cells of humans. Iron is naturally released to surface waters through weathering of iron bearing minerals, but significant amounts are also released through industrial processes, corrosion of iron and steel, and discharges from mining operations. Iron concentrations in freshwater on the Canadian prairies can range as high as 14 mg/L. This, however, is rare. Levels of iron in water above 0.3 mg/L can lead to staining of laundry and plumbing fixtures, while higher concentrations can impart a metallic taste and yellow precipitate in the water. If concentrations exceed 0.5 mg/L it may interfere with zeolite water softening. Excessive levels of iron in water may also indicate environmental stresses such as acidification and anaerobic conditions (i.e. lack of oxygen).

Iron (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.3 (A)		0.3	5.0	
Objective	0.3 (A)		1.0	5.0 - 20.0	

(A) = Guideline or objective based on aesthetic considerations

Lead (mg/L) (Pb)

Lead is a common heavy metal found in the earth's crust. It is found in at least 200 different minerals, most of that are rare, with the exception being the mineral galena. Lead is used in the production of storage batteries and is an important ingredient in the manufacture of numerous chemical compounds used in a variety of industries. Weathering of minerals containing lead is the main natural pathway for entering surface waters. Significant amounts of lead are also released in metal smelting emissions, and mine and industrial effluents. The North American ban on lead based additives to automotive fuel has eliminated the formerly high emissions from automobile exhaust. Levels of dissolved lead in natural surface waters are generally quite low (0.001 - 0.050 mg/L in Canadian waters). The chemistry of lead in the aquatic environment is relatively complex and not fully understood. Lead tends to bind with organic material to form soluble, colloidal (suspended), and particulate compounds. Dissolved oxygen, hardness, pH, and the concentration and composition of inorganic and organic matter all appear to affect the concentration of lead in surface water. Lead is bioaccumulated (stored in tissues and organs) by plants and animals, and can have toxic effects on organisms that experience prolonged exposure; even at low concentrations. The Health Canada maximum acceptable concentration guideline for lead in drinking water is 0.010 mg/L. This guideline is based on long-term exposure and concentrations slightly or periodically above the guideline may not necessarily pose a health risk.

Lead (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.01 (H)	0.1	0.001 - 0.007*	0.2	
Objective	0.05 (H)	0.5	0.0013 0.0077*	5.0 - 10.0	

(H) = Guideline or objective based on health considerations.

* Guideline/objective changes with hardness.

Lindane ($\mu\text{g/L}$) ($\text{C}_6\text{H}_5\text{Cl}_6$)

Lindane (γ -isomer of 1,2,3,4,5,6-hexachlorocyclohexane) is used for insect control in agricultural and silvicultural applications and in dips, dusts, and sprays for livestock and pets. Like most pesticides, lindane can enter the aquatic environment through run-off from cultivated land, accidental spillage, aerial drift, unintentional overspray of adjacent water bodies, poor disposal and equipment cleaning techniques, and urban sewage. Most studies indicate that lindane is relatively stable in the water column. However, in biologically active aquatic environments lindane can be biologically transformed with half lives of several days to more than a year. Lindane may be bioaccumulated in aquatic organisms. In high enough concentrations, lindane can be toxic to fish as well as insects including bees.

Lindane ($\mu\text{g/L}$)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	4 (H)		0.08		
Objective					

(H) = Guideline or objective based on health considerations.

Magnesium (mg/L) (Mg^{+2})

Like calcium, magnesium is an abundant element in surface water supplies. Weathering of igneous and sedimentary rock (e.g. dolomite), in that it is a common constituent, are the main natural sources of magnesium in surface waters. Significant contributions to surface waters can also originate via effluent from chemical and textile manufacturers, tanneries, and cement plants. Magnesium is an essential element for enzymatic activity and protein synthesis in plants and animals. It is also an important component of chlorophyll in plants. Levels of magnesium in surface waters of western Canada range from 0.03 to 168.0 mg/L. There are no drinking water guidelines for magnesium. However, along with calcium, it is a major contributor to water hardness. Water with high levels of magnesium (>150 mg/ml) can have taste problems, and prolonged consumption may cause diarrhea.

Manganese (mg/L) (Mn^{+2})

Manganese is a heavy metal that is essential, in trace amounts, for the normal growth and development of plant and animal life. Natural sources of manganese in water result from weathering of mineral deposits, where it is often associated with iron. As such, manganese levels in surface waters are usually closely correlated with iron levels. High levels of manganese in drinking water result in taste problems, staining of plumbing fixtures, and may promote the growth of certain micro-organisms in treatment systems. Manganese is usually present in surface waters at concentrations less than 1.0 mg/L.

Manganese (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	0.05 (A)			0.2	
Objective	0.05 (A)			0.2 - 10.0	

(A) = Guideline or objective based on aesthetic considerations.

MCPA ($\mu\text{g/L}$) ($\text{C}_9\text{H}_9\text{ClO}_3$)

MCPA ((4-chloro-2-methylphenoxy)-acetic acid) is a hormone-type phenoxy-acid herbicide used to control broadleaf weeds in cereal crops, pasture land, and lawn turf. Trade names for MCPA include Weedar® MCPA Concentrate, Brominal® Plus, Rhomene®, Rhonox®, and Chiptox®. Like most herbicides, MCPA can enter the aquatic environment through run-off from cultivated land, accidental spillage, aerial drift, unintentional overspray of adjacent water bodies, poor disposal and equipment cleaning techniques, and urban sewage. Dissipation in water is by photolysis (exposure to sunlight and ultraviolet radiation) and microbial degradation, and can be complete in 14 to 32 days. Little has been published regarding the toxicity of MCPA to humans and livestock. However, studies on long-term exposure point to kidney dysfunction as the main toxic effect on laboratory animals. There is also some suspicion that MCPA has an indirect carcinogenic effect on the liver. In light of this, a guideline for MCPA concentration in domestic water supplies is being developed.

MCPA ($\mu\text{g/L}$)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
CWQG		25	2.6	2.6	
MSWQO					

Nickel (mg/L) (Ni^{+2})

Nickel is the 23rd most abundant element in the earth's crust. It is commonly found in mineral deposits in association with antimony, arsenic, and sulphur. Nickel is a very important economic metal since it is used in the production of storage batteries, coins, and stainless steel and other corrosion resistant metal alloys. The majority of nickel production comes from sulphide minerals such as pentlandite ($(\text{FeNi})_9\text{S}_8$). Large pentlandite deposits are found near Sudbury, Ontario, making it one of the largest nickel producing regions in the world. Nickel enters surface water primarily through weathering of rocks and minerals, the burning of fossil fuels, and in mining wastewater. The occurrence of nickel in water results from the disassociation of soluble nickel salts. Nickel can occur in a number of ionic forms in water, but the most common form is as Ni^{+2} . Nickel can also combine with or become adsorbed to carbonates, iron and manganese oxides, silica, suspended particulate matter, and organic material in water. The solubility of nickel in water is influenced by pH and hardness. Generally pH values above 6.0 result in reduced concentrations of nickel in the water column. Concentrations of nickel in non-polluted surface waters in Canada are usually around 0.001 to 0.002 mg/L. However, nickel is bioaccumulated by some aquatic plants and animals, including fish. The guideline for nickel in human drinking water is currently under review by Health Canada.

Nickel (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline		1.0	0.025 - 0.15 *	0.2	
Objective		5.0	0.056 - 0.16 *	0.2 - 2.0	

* Guideline/objective changes with hardness.

Nitrate-Nitrite (mg/L) (NO_3^- , NO_2^-)

Nitrate (NO_3^-) and nitrite (NO_2^-) are two inorganic forms of nitrogen found in surface water. Along with ammonia, they are a very important source of nitrogen for aquatic plants. Nitrates are used extensively as an ingredient in nitrogen fertilizers. Thus, water run-off from cultivated land is a major source of nitrates in surface waters. Nitrates can also be added to surface waters through the decomposition of plant material and animal wastes, and leachate from igneous rocks. Generally nitrate levels in surface waters in western Canada rarely exceed 5 mg/L, and are usually below 1 mg/L. Nitrite is also found in surface waters, but usually at levels much lower than nitrate. Nitrite concentrations in natural settings are usually around 0.001 mg/L. Sources of nitrite include industrial effluents and animal waste. High levels of nitrates-nitrites in municipal or farm water supplies in rural Manitoba are usually a sign of poor sewage treatment and/or run-off from cultivated land (excessive crop fertilization) and feedlots/pastures. The maximum acceptable drinking water guideline set by Health Canada is 10.0 mg/L for nitrate (reported as nitrogen) and 1.0 mg/L for nitrite (reported as nitrogen). In combination (nitrate-nitrite reported as nitrogen) the concentration should not exceed 10 mg/L. Concentrations of nitrate-nitrite (as nitrogen) above 10.0 mg/L may result in 'blue baby' condition (methemoglobinemia) in infants, which, under certain conditions and prolonged exposure, can be fatal.

Nitrate-Nitrite (mg/L N)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	10.0 (H)	20.0			
Objective	10.0 (H)	10.0			

(H) = Guideline or objective based on health considerations.

Nitrogen - Total Kjeldahl (mg/L) (N in organic compounds and NH_3)

Kjeldahl (pronounced 'kell-dall') nitrogen is a measure of the sum of organic nitrogen and ammonia in a water body. By subtracting the amount of ammonia in the water one can calculate the amount of nitrogen that is bound up in organic molecules in live and dead aquatic organisms. Thus, total Kjeldahl nitrogen (minus ammonia) is indicative of the amount of biological productivity in a surface water supply. A maximum acceptable concentration guideline for total Kjeldahl nitrogen has not been set, however, guidelines are available for the inorganic forms of nitrogen; namely ammonia, nitrate, and nitrite.

Oxygen (mg/L) (O_2)

Oxygen, a gaseous element, is a requisite for most life on earth. Exceptions include a number of anaerobic bacteria species that are adapted to living in oxygen depleted habitats. Elemental oxygen is very reactive, and oxygen gas itself is composed of two tightly bound oxygen atoms (O_2). Sources of dissolved oxygen include the atmosphere and plant photosynthesis. Oxygen is moderately soluble in water and temperature, salinity, turbulence (mixing), and elevation (atmospheric pressure variations) affect its solubility. Solubility decreases as temperature, salinity, and elevation increase, and turbulence decreases. Decomposition of plant and animal material by bacteria and plant and animal respiration use up large quantities of dissolved oxygen. If inputs of oxygen are not kept in balance with oxygen consumption rates, then anaerobic (oxygen depleted) conditions may result. This can create odour and taste problems and affect the overall chemistry of the water body. There is no guideline or objective for oxygen in human or livestock drinking water or in irrigation water. However, to avoid anaerobic conditions and support aquatic life, it is recommended that oxygen levels be maintained between 5.0 and 9.5 mg/L (or 47 - 60% saturation depending on temperature). In the case of dugouts, this can usually be achieved through artificial aeration.

pH (pH units)

Water pH is a measure of the concentration of hydrogen ions (H^+) in the water. The concentration of H^+ in water determines the water's acidity. The pH is measured on a negative logarithm scale from 0 - 14. Therefore, the lower the pH value for a water sample, the higher the concentration of H^+ and the more acidic the water. A value of 7 pH units is neutral, while those above 7 are basic (i.e. alkaline). Knowledge of pH is important as it influences the concentration of a number of trace metals and the productivity of aquatic organisms. As well, chlorination of water for disinfecting purposes is less successful if pH is above 8.5. The pH can vary throughout the year, and guidelines and objectives are shown as ranges. Maintenance of pH within the guideline and objective ranges should be an important goal for all surface water supplies.

pH (pH units)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	6.5 - 8.5 (A)		6.5 - 9.0		5.0 - 9.0
Objective	6.5 - 8.5 (A)	5.5 - 9.0	6.5 - 9.0	5.0 - 9.0	6.5 - 8.5

(A) = Guideline or objective based on aesthetic considerations

Phosphorus, Total (mg/L) (P in a variety of inorganic and organic forms)

Phosphorus is an essential mineral nutrient for plant and animal life. In both cases it is a component of adenosine triphosphate (ATP), the molecule used in the storage and transfer of energy in living organisms. It is also important in the maintenance and growth of bone and teeth in humans. In aquatic settings it is often the nutrient that is most important in determining the overall productivity of the ecosystem. Phosphorus is a very reactive element and in nature always exists with other elements to form organic or inorganic compounds. The total phosphorus in water is a summation of dissolved forms, forms adsorbed to sediment particles, and compounds contained in the cell walls of aquatic plants and animals. Phosphorus compounds are released into surface water through weathering of soil and rock and the decomposition of organic material. Domestic and industrial sewage and run-off from fertilized cultivated lands and livestock areas also contribute significantly to the total phosphorus in surface waters. However, because it is rapidly taken-up and assimilated by organisms, phosphorus concentrations under natural conditions tend to be low. High concentrations of phosphorus have not been shown to be toxic to humans. However, in combination with other factors, high levels of phosphorus can result in excessive algae, fungal, and macrophyte (aquatic weeds) growth. Total phosphorus levels below 0.025 mg/L in Lake, ponds, and reservoirs, and less than 0.05 mg/L in rivers and streams usually do not result in excessive algae or macrophyte growth.

Phosphorus, Dissolved (mg/L) ($H_2P_0_4^-$, $HP_0_4^{-2}$, $P_0_4^{-3}$)

The dissolved phosphorus content of water refers to that portion of the total phosphorus content that is present in the water after filtration (0.45 microns). Generally these are phosphate ions that are not bound to suspended particulate matter or tied-up in living organisms. The most common ionic forms of phosphate found in water include phosphate ($P_0_4^{-3}$), dihydrogen phosphate ($H_2P_0_4^-$), and monohydrogen phosphate ($HP_0_4^{-2}$). It is these forms, often referred to as orthophosphates, that are available for up-take by plants. The concentration of dissolved phosphate ions in water is influenced by pH; the activities of fungi, bacteria, algae, and invertebrates; and the concentration and composition of trace metals, organic compounds, and other particulate matter in water.

Potassium (mg/L) (K^+)

Potassium is a major mineral element common in clay and sedimentary shales. Along with nitrogen and phosphorus, it is one of the most important plant nutrients. It is essential for enzyme

activity and the maintenance of turgor pressure, without that plants develop weak stem and root systems. It is also necessary for proper osmotic balance and nerve function in higher animals. Most potassium in surface waters originates from leaching and weathering of soils that release potassium salts. Potassium salts are generally very soluble in the aquatic environment, therefore potassium is found mainly in its ionic form (K^+) in water. Concentrations of potassium in surface waters rarely exceed 20 mg/L, although ranges as high as 33.0 mg/L have been recorded in western Canada. There are no maximum acceptable guidelines or objectives for potassium in surface water supplies. Although one is very unlikely to encounter it in a natural setting, levels above 2000 mg/L can be toxic to humans.

Simazine ($\mu\text{g/L}$) ($\text{C}_7\text{H}_{12}\text{ClN}_5$)

Simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) is an organonitrogen herbicide used extensively across Canada as a mechanism for control of annual grasses and broad leaf weeds, primarily in corn, established alfalfa, orchards and for weed control in drainage ditches. Simazine is distributed under a number of trade names in Canada, including: Simazine Atanor®; Simazol®; Princep®; Caliber®90; Gesatop®; Primatrol S®; Drexel® Simazine; Simanex®; Sim-Trol®; and Nezitec®. Simazine enters the aquatic environment through production, accidental spillage, use, and disposal. Simazine is removed from water via microbial and chemical degradation. Simazine can persist in flooded soils for up to three years. Simazine in the presence of intermediary nitrate has been classified as being potentially carcinogenic to humans.

Simazine ($\mu\text{g/L}$)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
CWQG	10 (H)	10	10	5	
MSWQO					

(H) = Guideline or objective based on health considerations.

Sodium (mg/L) (Na^+)

Sodium is the sixth most common element in the earth's crust. Sodium is essential for nerve function and water balance in higher animals, but is usually a deterrent to proper growth and development in plants. Weathering of salt rock deposits is the main natural source of sodium in surface water. Concentrations in surface waters, therefore, can vary greatly geographically because of spatial variation in mineral deposits. Prolonged exposure to concentrations above the guideline and objective can be a factor in kidney, circulatory, and heart diseases in humans. Consultation with a physician is recommended for those on restricted sodium diets whose drinking water approaches or surpasses the guideline or objective. It should be noted that some water softeners, used to reduce water hardness, will increase the levels of sodium in drinking water.

Sodium (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	200 (H)				
Objective	400 (H)	1000		20.0 *	

(H) = Guideline or objective based on health considerations

* Objective is dependent on the sodium absorption ratio (SAR) of the soil.

Sulphate (mg/L) (SO_4^{2-})

Sulphate is a negatively charged ion composed of one atom of sulphur and four atoms of oxygen. Sulphur, in low concentrations, is an essential element for plant and animal life. It is through the intake of the sulphate ion that plants obtain their sulphur requirement. Sulphate is second only to the carbonate ion (CO_3^{2-}) (see alkalinity) in abundance in surface waters. It originates from sedimentary rocks such as

shale, as well as from industrial effluents and mine drainage wastes. The use of blue-stone (copper sulphate) for algae control can also lead to increased levels of sulphate in water. Excessive sulphate levels can have a laxative effect on consumers.

Sulphate (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	500 (H)	1000			
Objective	500 (H)	600		250	

(H) = Guideline or objective based on health considerations.

Total Dissolved Solids (mg/L)

Total dissolved solids is a measure of the filterable salts and minerals in a water sample. High total dissolved solids concentrations usually result in poor taste and may, if high enough and depending on the composition, become a health concern. Total dissolved solids may consist of a single dominant solute (salt or mineral) or a large number of different solutes salts depending on the water source.

Total Dissolved Solids (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	500 (A)	3000		500 - 3500	
Objective	500 (A)	3000		700 - 1400	

(A) = Guideline or objective based on aesthetic considerations.

Total Suspended Solids (mg/L)

Total suspended solids is the non-filterable residue in a water sample. As the name implies, it refers to suspended rather than dissolved particles, and includes clay, silt, large inorganic and organic molecules, and even small aquatic plants and animals. Land run-off and algal blooms are major contributors to the level of total suspended solids in surface waters. High levels of total suspended solids in a water body result in a lower degree of light penetration. This may be advantageous in that it leads to a decline in algae and weed growth. However, it can lead to problems with water intake filters, decrease the success of chlorination, and reduce suitability for desirable aquatic organisms. There are no guidelines for total suspended solids surface water supplies, however, an objective of 25 mg/L has been set by Manitoba Environment for the protection of aquatic life.

Trifluralin (µg/L) (C₁₃H₁₆F₃N₃O₄)

Trifluralin (a,a,a-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine) is an organonitrogen-based, fluorine containing, pre-emergence herbicide used for control of broadleaf weeds and grasses in a number of cereal, grain, and vegetable crops. In Canada it is sold in large amounts under a number of trade names, including Treflan®, Triflurex®, Rival®, and Fortress®. Trifluralin is a very volatile herbicide in that it evaporates easily into the air following application. It has a relatively low solubility in water. Thus, transport in run-off water from cultivated land into adjacent surface water supplies is usually minimal. As such, pathways into the aquatic environment tend to be via accidental spills, improper disposal, cleaning of equipment, aerial drift, and accidental over-spray of adjacent water bodies during application. Once in water, trifluralin is broken down by sunlight, degraded by microbial activity, and lost to the atmosphere through volatilization. The rate of dissipation in water is not known, but is likely dependent on temperature, exposure to sunlight, and water clarity factors such as turbidity, colour, and organic matter content. Tests have shown that trifluralin in water can be removed by reverse osmosis, granular activated charcoal, and alum treatment of the water body. The acute toxicity of trifluralin is low, but chronic (prolonged or constant) ingestion can cause weight loss, increased liver size, and kidney problems. Health Canada has established interim guidelines for trifluralin in water.

These may be altered once investigations into the possible carcinogenic properties of the herbicide have been conducted.

Trifluralin (µg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	45 (H)	45	0.1		
Objective					

(H) = Guideline or objective based on health considerations

Turbidity (NTU)

Turbidity is a measure of light penetration through the water column. As such, it is directly related to total suspended solids, and is often used to indicate overall water clarity. Water turbidity is an important consideration in the design of drinking water treatment systems since the success of disinfecting by chlorination is related to the amount of suspended solids in the water. In the case of high turbidity values, water treatment systems have to be designed to remove suspended particles from the water prior to chlorination, otherwise chlorination is unsuccessful and/or trihalomethanes can be produced.

Turbidity (NTU)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	1.0 (H); 5.0 (A)				
Objective	5.0 (A)				50.0

(A) = Guideline or objective based on aesthetic considerations.

(H) = Guideline or objective based on health considerations.

Zinc (mg/L) (Zn⁺²)

Zinc is a heavy metal that is necessary in trace amounts for plant and animal life. In animals it is involved in the activities of digestion enzymes, while in plants it is an important element in chloroplast and hormone production. Zinc is the 24th most abundant element in the earth's crust. It is found mainly in sulphide, carbonate, and silicate minerals. Sulphide minerals containing zinc (e.g. zinc blende (ZnS)) are generally associated with iron, copper, and lead deposits, and zinc production is a by-product of mining for these elements. Zinc is used as a protective coating for iron and steel and as a component in numerous metal alloys such as brass (with copper) and bronze (with copper and tin). Zinc enters the aquatic environment through weathering of minerals and rocks, and through mining waste, sewage, and landfills. In water it exists in many suspended and dissolved forms; from simple ions (Zn⁺²) through to complexes in that it is bound to clay and organic particles and colloids. Overall concentrations of zinc in water tend to be relatively low, and in non-polluted surface waters rarely exceed 0.10 mg/L in Canada. Some zinc does find its way into drinking water because of the use of zinc in plumbing materials. The major source of zinc in the human diet is through food. Ingestion of zinc higher than the recommended daily requirement of 4 - 10 mg has no adverse affect on health. However, excessive concentrations of zinc in drinking water can cause taste problems.

Zinc (mg/L)	Water Use Category				
	Domestic	Livestock	Aquatic Life	Irrigation	Recreation
Guideline	5.0 (A)	50.0	0.03	1.0 - 5.0 *	
Objective	5.0 (A)	50.0	0.047	2.0 - 10.0*	

(A) = Guideline or objective based on aesthetic considerations. * Guideline/objective changes with pH.

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